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Myopic Traction Maculopathy: A New Perspective on Classification and Management

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Abstract: Myopic traction maculopathy (MTM) is a complex disease affecting approximately 30% of eyes with pathologic myopia. A review of the history of treatment of MTM with success rates and limitations of different surgical techniques are reported.

The pathogenesis, the definition and the management were clarified in a recent study(cit). The MTM Staging System (MSS) table summarizes all the stages of MTM offering insights on the pathogenesis and natural evolution of the disease.

Guidelines of management of MTM were therefore proposed, but customized for each stage.

Initial stages 1a and 2a, which define maculoschisis in the inner or inner-outer or only outer layers of the retina, should be observed. Stages 3a and 4a, defining macular detachment with and without associated schisis, should be treated with a macular buckle (MB).

Stage 1b, which is a lamellar macular hole in a myopic eye, should be treated with pars plana vitrectomy (PPV) only in symptomatic cases. Stages 2b, 3b, and 4b should be treated with a MB and PPV should be added in a second step only if the presence of a lamellar macular hole requires intervention to improve visual function.

Stage 1c, which is a full thickness macular hole in a myopic eye, should be treated with PPV. Stages 2c, 3c and 4c should be treated with a combination of simultaneous MB + PPV to treat both the retinal pattern of schisis or detachment and the full thickness macular hole.

Key Words: macular buckle, myopia, myopic traction maculopathy, staphyloma, retinoschisis

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MYOPIC TRACTION MACULOPATHY

Myopic traction maculopathy (MTM) is a wide spectrum of clinical pictures that may affect up to 30% of eyes with pathologic myopia (PM)[1] with and without posterior staphyloma.

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WHAT ARE THE UNMET NEEDS FOR THIS DISEASE?...

At the moment, we can find in literature different proposals of classification for MTM.[2–4] However, none of them is comprehensive, nor fully capable to explain the pathogenesis and natural history.

Furthermore, there is no consensus on the complete terminology of the different types of MTM, nor on treatment.

...AND HOW TO MEET THEM

In this review we will report the new MTM staging system,[5] a recently published new classification that highlights the dynamic and continuous evolving nature of the disease. Then we will offer guidelines for the management customized for each stage.

DEFINITIONS OF MYOPIC TRACTION MACULOPATHY

Different definitions of MTM may be found, from macular schisis-like thickening of the retina to foveal detachment, macular foveoschisis, foveoschisis, and shallow macular detachment (MD).

The first description of cases with suspect forms of MTM was given by Phillips in 1958,[6] reporting as "retinomacular schisis" a posterior retinal detachment without macular hole, in patients with myopic staphyloma, assuming a tractional pathogenesis.

Only 40 years later, in 1999, the advent of optical coherence tomography (OCT) allowed Takano and Kishi to publish the anatomical characteristics of what they defined as "foveal retinomacular schisis."[7]

Panozzo et al[1] first coined the term "myopic traction maculopathy" and established that MTM may affect patients with high myopia and posterior staphyloma in 9% to 34%.[1]

Shimada et al[3] described different stages of the macular foveoschisis, leading to a foveal detachment, through the formation of an outer lamellar hole (O-LMH).

Ruiz Moreno et al[4] published a classification not just of MTM but of myopic maculopathy, addressing, as a whole, the atrophic, tractional and neovascular aspects of PM. According to them, MTM is the tractional side of the ATN classification.[4]

Recently, Parolini et al[5] have proposed a new classification that was specific for MTM and defined it as a progressive disease that first involves the innermost layers of the retina with an inner macular schisis (I-MS) and gradually progresses, involving the outermost retinal layers, until a MD appears, whereas the schisis disappears. The MTM Staging System (MSS) differs from all other classifications already published on MTM because it provides in one table (MSS Table) information of nomenclature, pathogenesis, and prognosis of MTM. Furthermore, for the first time, the MTM classification is presented as a staging system, to highlight the evolving dynamic nature of the disease.

It is reported that about 50% of patients affected by MTM progresses to major complications such as full thickness macular hole or MD within 2 years.[8] However, according to the studies of Parolini et al, MTM is a dynamic disease that is slowly progressive in stage 1 and 2 and that eventually evolves over time into more severe stages 3 and 4, in virtually every eye in which it manifests.

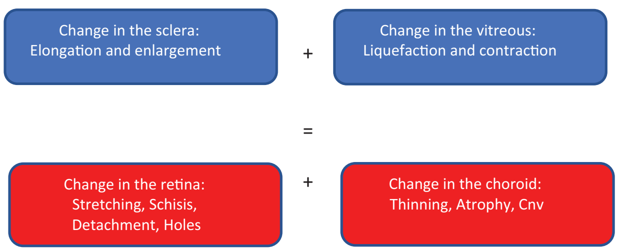
PATHOGENESIS: THE GAME OF FORCES

The pathogenesis of MTM was reported to be multifactorial, mostly linked to the rigidity of inner limiting membrane (ILM) and to the anteroposterior tractions caused by epiretinal affections.

Our theory is that the key factors are the continuous change in the shape of the eyewall, in terms of elongation and enlargement, in different directions, according to the shape of the orbit. The change in the eyewall is followed by thinning and stretching of each layer of the posterior eyewall, sclera choroid, and retina.

The dynamic change in the external side of the eye is accompanied by the change in the texture of the vitreous.

Change in the sclera and change in the vitreous have consequences on the retina and choroid.



The retina is a multilayered multicellular structure, which is held together, as a unique tissue, by tangential centripetal forces, mainly exerted by the Muller cells and by the external and internal limiting membranes.

In PM, different centrifugal forces tend to modify the shape and the location of the retina and the fovea from the natural one, racing against the centripetal intraretinal force. These centrifugal forces are exerted by the vitreous and the sclera, with 2 main different directions: tangential or perpendicular to the retinal tissue.

This Game of Forces is a “push and pull game” played by vitreous and sclera, which modifies the retina and leads in the macula to the different clinical pictures of schisis, detachment, and holes.

The progression of the stages depends on the prevalent centrifugal forces exerted on the retina and on the inner fovea.

If the prevalent centrifugal forces are perpendicular to the macular plane, the pulling effect is in the direction anteroposterior to the retina. Therefore, the inner schisis progresses and involves the outer layers becoming an inner outer-schisis, a pure outer-schisis, and eventually a MD. Although the outer component further progresses to MD, the inner component of schisis is progressively relieved because the intraretinal force becomes progressively prevalent, as the retina detaches from the RPE. Therefore, when the retina is totally detached, we no longer observe a schisis.

If the prevalent centrifugal forces are tangential to the macular plane, the pulling effect is in the fovea, which is laterally stretched. The eye will develop an inner lamellar macular hole (I-LMH) and eventually a FTMH.[9,10]

Once the macula is detached, the tangential forces may also influence the outer layers, and a disruption and splitting of the ellipsoid zone band might occur, generating an outer lamellar macular hole (O-LMH).

When Both the Perpendicular and the Tangential Forces Act Together, a MD with Either Lamellar or FTMH will Appear

THE MYOPIC TRACTION MACULOPATHY STAGING SYSTEM

The stages of the MSS are depicted in Figure 1.

At the stage of maculoschisis, MTM can be classified in stage MSS 1 (inner or inner-outer schisis) and stage MSS 2 (purely outer schisis), a separation of retinal layers.

MTM further progresses into MD, or stage MSS 3, which is a separation between the RPE and photoreceptors layers,[11–13] initially limited to the posterior pole.

Stage 3 evolves into stage MSS 4, that describes a MD extended to the whole posterior pole, whereas the schisis in the retina disappears, as the intraretinal stretching is released by the detachment of the outer retinal layers from the RPE.

Epimacular abnormalities may often be detected as the hyper-reflective lines overlying the retina. They have been described as important contributors to the occurrence macular schisis.[14] However, we have noticed that MTM might evolve even in vitrectomized eyes usually in the form of MD without a macular hole.

Splitting in the photoreceptors in the O-LMH contributes to visual loss and may have a predictive value for the postoperative visual recovery[15] (Fig. 2).

Wang et al[16] noted that the reduced best-corrected visual acuity (BCVA) in MTM with maculoschisis results from foveal distortion rather than photoreceptor damage. A correlation between the full and outer retinal volumes and reduced visual acuity was demonstrated; this in presence of an intact ellipsoid zone. Müller cells play a key role in the functional integrity of the retina, therefore, the mechanical distortion caused by MTM may damage the Müller cells function, reducing BCVA.

HOW DO WE DIAGNOSE MYOPIC TRACTION MACULOPATHY?

Indirect ophthalmoscopy and biomicroscopy are extremely limited in detecting signs of MTM because of the extreme retinal transparency and choroidal thinning.[7] OCT is the key instrument to diagnose this disease[1,17] (Fig. 2). In fact the true description of MTM began with the advent of OCT.[1]

However, when studying an eye with MTM through OCT, it should be known that the most efficient procedure is to use wide scans and to study the entire posterior pole. In fact, MTM might start in a location outside the posterior pole and then progress. OCT scans taken in different areas and direction can offer completely different information (Fig. 2).

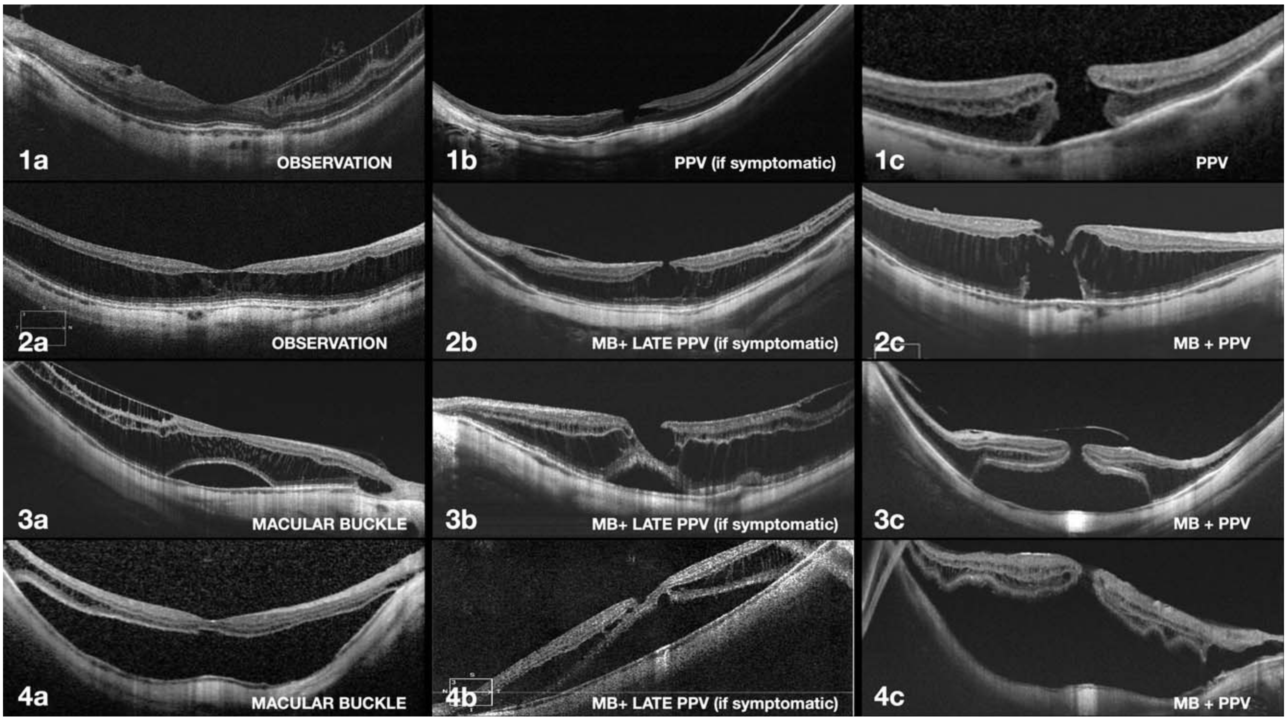


FIGURE 1. The MTM Staging System Table. This table describes all the 12 stages of MTM. In the rows from 1 to 4, the Table shows the evolution perpendicular to the retinal plane from schisis to complete macular detachment. In the columns from a to c, it describes the evolution tangential to the retinal plane from normal fovea to inner lamellar macular hole to full thickness macular hole. At each stage, the advice of management is provided. MB indicates macular buckle; MTM, myopic traction maculopathy; PPV, pars plana vitrectomy.

HOW DO WE DIFFERENTIATE THE MYOPIC TRACTION MACULOPATHY STAGING SYSTEM CLASSIFICATION COMPARED TO THE CLASSIFICATION PROPOSED BY SHIMADA AND BY RUIZ MORENO ET AL?

The classification by Shimada et al[2] describes the retinoschisis in 5 stages (from 0 to 4) based on the size and location of the schisis in relation to the fovea. It is an anatomical classification that does not mention the evolution into detachment.

A second classification by Shimada et al[3] describes the evolution from schisis to detachment through an outer macular hole. It does not comprise all the stages.

Ruiz Moreno et al proposed a classification not just of MTM but of myopic maculopathy, that is known as ATN classification, considering the 3 main aspects of myopia, A as atrophy, T as traction, and N as neovascularization. The T session is the one dedicated to MTM but it is not complete.

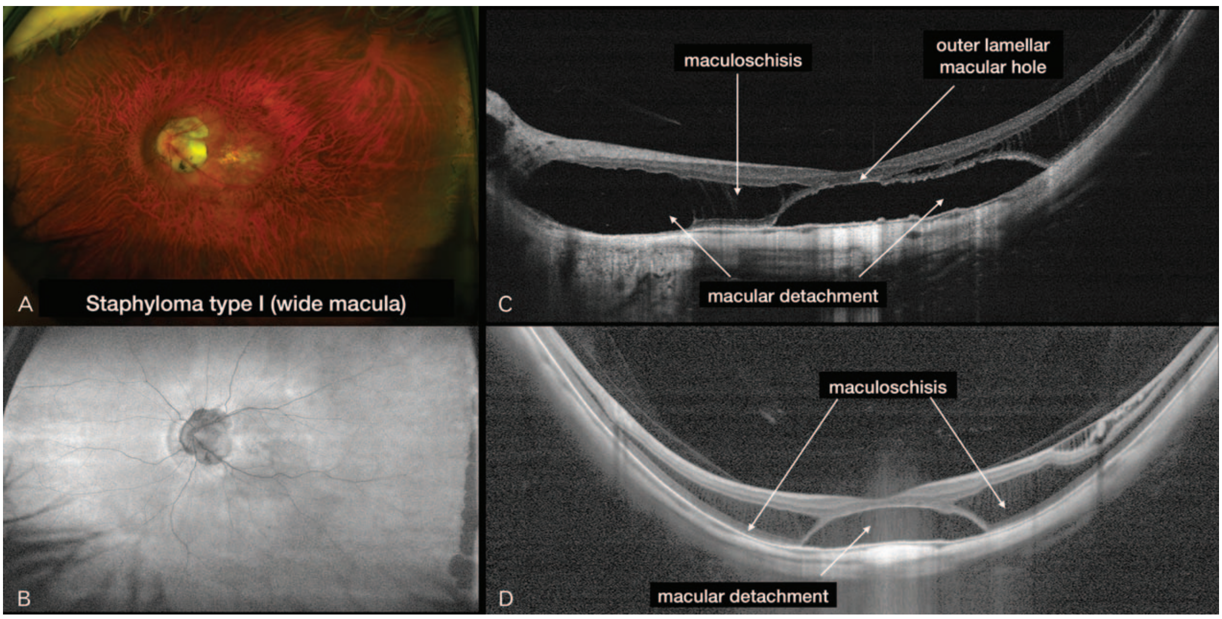


FIGURE 2. A, Colour wide fundus photo of an eye with pathologic myopia and posterior staphyloma. B, Autofluorescence of an eye with pathologic myopia and posterior staphyloma. C, Optical coherence tomography (OCT) of the macular area of the same eye. Horizontal scan 12 mm. D, OCT of the same eye. Vertical scan 12 mm.

WHEN DOES MYOPIC TRACTION MACULOPATHY AFFECT IN LIFE?

PM usually begins in childhood, but the appearance and progression of MTM depend more on the age of presentation of PM (and therefore duration of PM) than on the age of patients. Parolini et al[5] found that patients in Stage 1 have an average age of 53 years. This is at least the average age at which the patients undergo an OCT examination. However, MTM may be totally asymptomatic especially in early stages.[12] As a consequence of the lack of symptoms, the disease could be underestimated.

The symptoms usually reported by patients are: blurred vision, reduce visual acuity, central scotoma, and metamorphopsia.[1]

HOW DO WE KNOW THAT MYOPIC TRACTION MACULOPATHY EVOLVES?

Parolini et al[5] studied 72 eyes with MTM, collecting the OCT of the patients taken at different timings in their lives. By doing so, they could appreciate how in the same eye MTM evolves, starting between 40 and 60 years of age (Fig. 3). They also collected the data of visual acuity of the same eyes, in different stages of MTM, and could appreciate how visual acuity deteriorates, as MTM progresses to more severe stages.

MANAGEMENT OF MYOPIC TRACTION MACULOPATHY

What Techniques Have Been Discarded and Why?

The Past Always Teaches to Understand The Present

Looking at the history of treatments of MTM is useful to better comprehend which techniques were successful or not and why.

Certainly, the first approaches were directed to solve only the most severe forms of retinal detachment associated with macular hole (now known as MSS stage 4c).

Certainly, the aim was only to restore anatomy and *did not* guarantee an acceptable functional recovery.

It all Started by Shortening the Eye...

The idea of preventing axial elongation and scleral growth, in myopic eyes, by the placement of material over the posterior part of the eye was proposed many years before knowing what MTM really was.

Shevelev[18] first proposed, in 1930, the transplantation of fascia lata for scleral reinforcement.

In 1957, Schepens et al revised the macular buckling procedures.[19] The injection of gas was counseled in the cases in which the detachment persisted (Strampelli 1957).[20]

Borley and Snyder[21] and separately Curtin[22] described a technique for the placement of grafts of donor sclera.

In 1972, Snyder and Thompson[23] published a modified scleral reinforcement. Momose[24] introduced Lyodura, derived from cadaver dura mater, in 1983. Curtin and Whitmore[25] in 1987 had negative conclusions on the outcomes for their reinforcement techniques. However, Thompson and Pruett,[26] in 1990 and 1995, expressed satisfaction with the efficacy and safety of their case series.

From 1957 to the 1980s, the criterion standard for the treatment of MD with macular hole was definitely the macular buckle (MB).[19,20,27–34]

But

Was it Easy to Place a Buckle Behind the Macula?

No! After all, to suture a piece of sponge or dura mater or any other material to shorten the eye, to find ways to expose the macular sclera, to detach muscles, to find the right spot and where to place the buckle were challenging and time-consuming procedures even for the most experienced surgeons.

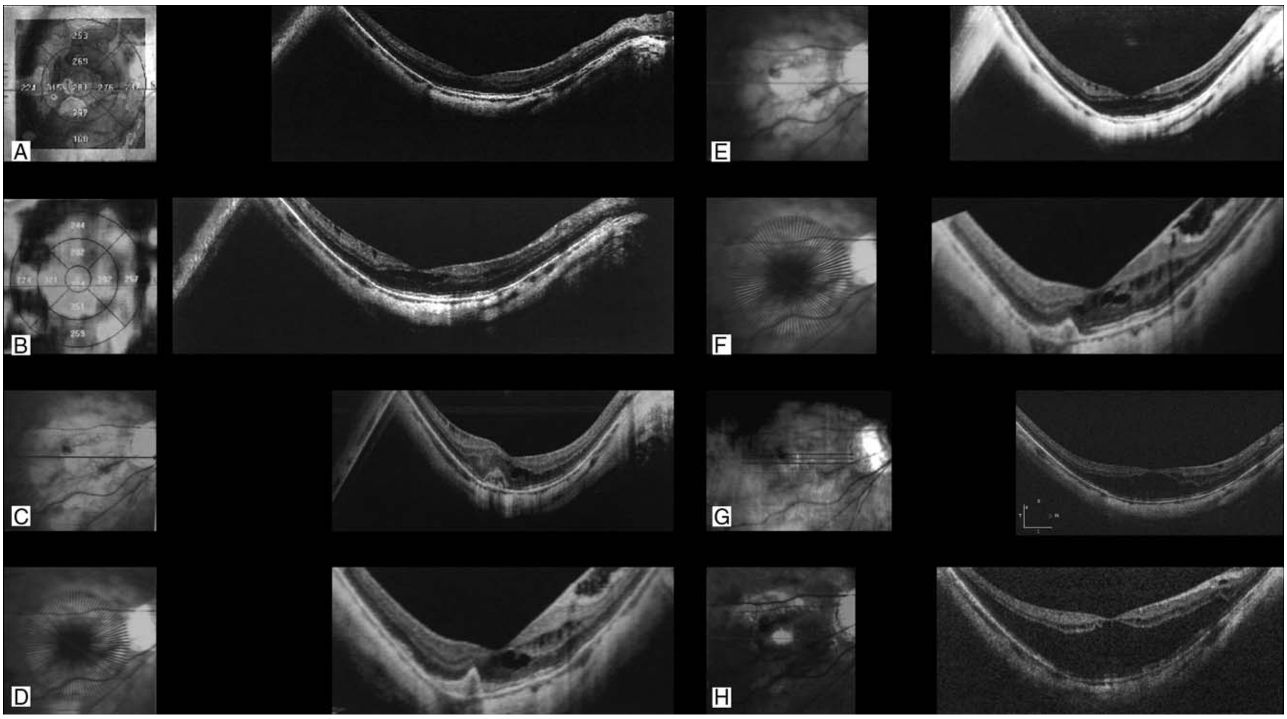


FIGURE 3. Example of natural evolution of myopic traction maculopathy in the right and left eyes of the same patient. A, The patient is 45 years old and the optical coherence tomography (OCT) shows a mild inner macular schisis. B–H, OCT showing a deepening of the maculoschisis in the outer layers.

Was Placing a Buckle Free of Complications?

After all, suturing anything to a thin sclera implied possible perforation and hemorrages in the macular areas

Then Vitrectomy Came Available. So Why not Approaching Even Myopic Eyes From the Inside? Could it be Easier? Could it be more Successful Than Buckle?

The first article that considered pars plana vitrectomy (PPV) for the MHMD was published in 1982[35] by Gonvers and Machemer. Many authors published afterwards,[36,37] proposing different approaches with different tamponades.

First Gas...

PPV with gas was linked to a high rate of MD failure or relapse.

Then Silicone Oil...

In 1999, Wolfensberger et al[38] proposed the use of silicone oil associated to the laser treatment of the hole and obtained 92% of retinal reattachment, but, as expected, poor increase in vision.

Lu et al[39] in 2002 compared various methods of PPV, associating the injection of gas, with and without laser treatment of the macular hole, and injection of silicone oil without laser treatment, demonstrating the superiority of the first method, with a success rate of 93%, 58%, 57%, respectively, giving a key role to laser treatment for anatomic success. It must be highlighted, however, that functional results were still very poor.

Kuhn[40] in 2003 made, first, the consideration that the retinal detachment preceded the formation of the macular hole in these eyes just because, by comparison with emmetropic eyes, macular hole never causes retinal detachment. In the same year, Kanda et al[41] presented 2 patients with retinomacular schisis and retinal detachment without a macular hole. The 2 cases were treated with 20G PPV, peeling of the ILM to the vascular arcades after staining with indocianine green and tamponade with 13% to 14% perfluoropropane (C3F8), plus facedown positioning for 7 to 10 days.

In 2004, Ikuno et al[42] applied PPV to 5 eyes with macular schisis without a macular hole. In 30% of the eyes, only a significant reduction but not resolution of retinal detachment was noticed.

In 2006, Chen[43] reported the retinal reattachment success rate, from 50% to 60% after PPV and gas injection.

Panozzo et al,[17] in 2007, carried out the first large-scale surgical work on MTM. The study consisted of 24 eyes (5 with detachment and 19 with schisis), followed for 5 years, and treated with the sole purpose of removing the vitreous-retinal traction without using tamponade. He reported complete resolution of MTM stable in time in 95.8%. Four of the 5 eyes with MD and 1 eye with retinomacular schisis developed; however, a macular hole that did not hesitate in a new MD and an eye remained unchanged. As for the visual recovery, 70% improved and 30% remained unchanged.

Then Heavy Silicone Oil...

Different authors[44,45] presented promising results with the use of heavy silicone oil (HSO) in the cases failure of other tamponades. However, after removal of HSO, retinal detachment was still reported.

In 2011, our group[46] compared the results of standard silicone oil 1000 cSt and heavy silicone oil in the ability of reattaching the retina and closing the hole in 42 cases of MHMD. The anatomic results were similar, with a macular reattachment rate of 76.5% and 81.8% for SO and for HSO respectively. The frequent relapses of MD in both groups were always linked to reopening of the hole. We concluded that there was a high recurrence rate of retinal detachment and an unsatisfactory final BCVA with both tamponades.

How to Address the Macular Hole Issue in a Long Eye and Not Just the Detachment

The difficulty of closing a macular hole in a highly myopic eye is testified by the variety of peculiar techniques proposed in the past like the transcleral diathermy around the macular hole, or the exposure of the retina to ultraviolet light, associated to the injection of hypertonic saline in the subtenon space, to induce chorioretinitis (Arruga 1952, Dellaporta 1953, Madroszkiewicz 1958). Macular hole photocoagulation seemed to add anatomical success but certainly not functional.[38]

What About the Peeling of the Inner Limiting Membrane?

The peeling of the ILM seemed to improve the range of success of PPV in terms of closing macular holes.[47]

On the contrary, it was also well published that ILM peeling increased the risk of inducing an iatrogenic FTMH[48] in cases of MDs without a macular hole (stages 3a or 4a) at presentation. Therefore, it was suggested to avoid peeling the ILM when a hole was not present. Some authors also published on PPV with foveal sparing ILM peeling to treat MTM, reporting an improvement of BCVA and an anatomical resolution of the macularschisis.[49–54]

Recently, an increasing number of articles have been published, showing that, if the ILM is not completely removed and an ILM flap is left, this improves the chance to close a macular hole even in myopic eyes.[55,56]

The success of PPV in high myopic MD remains limited with any tamponade, mainly because of the high rate of recurrence of retinal detachment, failure to close the hole when present, and risk to induce an iatrogenic macular hole when not previously present.

Therefore Back to Buckle!

The unsatisfactory results of PPV left open the way to a new course of publications on buckling the macula, which started again, after 20 years, in 2000 with Sasoh.[57]

In 2001, Ripandelli et al,[58] and later in 2005 Theodossiadis and Theodossiadis,[59] described MB success with a sponge and with a solid silicone exoplant respectively.

Some authors started to find a way to make the buckling technique easier, first of all with different buckle designs.

Tanaka et al[60] published in 2005 the successful approach of a new semirigid rod-exoplant in MHMD recurrences after PPV. The exoplant consisted of a T-shaped semirigid silicone rubber rod internally reinforced with titanium wires and an indenting head at one end.

In 2009, Parolini presented the 2 years' results of a new design of MB, at the Heatam meeting in Amsterdam. The idea was to propose a L-shaped buckle, made with a titanium stent inserted into a silicone sleeve, with the aim to obtain a macular indentation but allowing an anterior suture. The shape resembled the Ando plomb with the difference of using a titanium stent (MRI-compatible), not stainless-steel wire, and soft silicone sponge, not solid silicone, to indent the macula.

In 2012, Tian et al[61] applied the technique of macular buckling in 5 cases of MHMD after initial failure of pars plana PPV with ILM peeling and silicone oil tamponade. By doing so, the retina was reattached but, visual acuity did not improve and macular holes were closed only in 2 patients.

Alkabes[62] published a 16-year review on MB for MTM and compared the results with PPV. She concluded that the complete resolution of foveoschisis, retinal reattachment, and MH closure seem to be achieved more frequently with MB than PPV.

What Do We Learn From This Review of the Literature and History of Treatment of Myopic Traction Maculopathy?

Vitrectomy is easier then macular buckle with the available techniques.

Vitrectomy is linked to a high rate of recurrence of detachment and iatrogenic macular hole (when operating cases with no macular hole in the beginning).

Macular buckle shows a higher success rate of MD.

Macular buckle cannot close a macular hole.

ILM peeling and ILM flap can close a macular hole in a high myopic eye.

Let's Highlight the Limitations of the Published Articles on Myopic Traction Maculopathy

The follow-up is generally short.

The first row of papers on macular buckle could not be supported by OCT.

The second row of papers on macular buckle proposed it only for end-stage MTM and after failure of vitrectomy.

Surgical reports on MTM did not distinguish the result in relation to the MTM stage.

So Which is the Right Choice: Buckle or Vitrectomy, With and Without Peeling, With and Without Flap?

Since 2000, the unsatisfactory results obtained with PPV alone (both with and without peeling, and with any type of tamponade) by our group[46] and by other authors lead to the idea that it was not possible to propose one standardized type of treatment for each stage of MTM.

Therefore, we felt induced to further explore the feasibility of macular buckling technique. Our aim was to investigate a new model of MB that could be easier to implant, to allow a wider use of the technique.[34] The MB technique that we currently use is described elsewhere.[34]

In this section we will demonstrate that the frequently assisted debate "better buckle or vitrectomy" for MTM is not supported by evidence. The 2 techniques simply address 2 different problems and should be selected case by case or combined when necessary.

PROPOSAL OF NEW GUIDELINES FOR THE MYOPIC TRACTION MACULOPATHY TREATMENT

The goals of surgery need to be not only anatomical but also functional.

The functional goals should be to improve or maintain central vision and the central visual field.

The anatomical goals should be retinal attachment and hole closure. However, in eyes with PM we should ideally aim not only to treat but also to prevent the progression of MTM, being PM a degenerative and progressive disease.

The target of anatomical treatment must be double: the foveal profile, on one hand, and the retina with the sclera, on the other. The alteration in the foveal profile has to be treated with PPV and the alteration into the retina and sclera with MB.

Parolini et al recently proposed (Macular Surgery Book \\ EJO, under review) new management guidelines of MTM, based on the MSS.

They evaluated the outcome of PPV, MB or combined MB + PPV surgery to treat 157 eyes affected by different stages of MTM.

Observing the anatomical results of the different treatments, they concluded that PPV better addressed the tangential tractions on the inner retinal surface, that is, the modulation of the foveal pattern, whereas the MB addressed the perpendicular tractions on the retina induced by scleral elongation, that is, the modulation of the retinal pattern.

What's the Evidence That These Guidelines are Correct?

If we do the opposite, that is, if we treat a prevalent tangential traction with a MB, and if we treat a prevalent perpendicular traction with PPV, potential severe complications might occur.

If only 1 component of traction is treated, the opposite component will manifest itself in time. Thus, whenever a combination of perpendicular and tangential forces is treated only with an MB, the perpendicular component is solved and the retinal pattern will improve, but the tangential force inducing alteration of the foveal pattern remains unchanged and might even worsen.

For example, if a patient affected by a mild and maculoschisis in stage 1a was to be treated with MB, the tangential tractions induced on the fovea by the buckle, pushing the retina vertically and anteriorly, could lead to an iatrogenic splitting of the fovea.

In the same way, when stage 2a, 3a or 4a are treated only with PPV, the schisis and detachment have a low chance to resolve or end up in iatrogenic macular hole.

Parolini et al assessed that stage 1a or 2a should be followed with observation every 12 to 18 months, as BCVA in these group is usually still good and the progression to the more severe stages is slow, unless significant epiretinal abnormalities are associated, in which case they should be treated like cases of ERM without MTM.

Mild schisis associated to lamellar (1b) of full thickness macular hole (1c) obtain a higher anatomical and functional success rate with PPV.

Stages 3a and 4a should be treated with MB alone because in those cases the tractions that detached the sclera from the retina are predominantly perpendicular to the macular plane.

Stages 2b, 3b, and 4b should be treated with MB alone first. PPV can be added in a later time only if necessary, thus restoring the foveal profile on an attached retina not affected by schisis nor detachment (Fig. 4).

It should be acknowledged that both MB and combined surgery resolve the schisis. Although the result of buckle is slow, progressive, and visible only in months, the result of subsequent or combined PPV is visible within 1 to 2 weeks. The surgeon should choose, case by case, whether a quick result is better than a slow result, which allows to avoid the consequences of PPV.

Macular schisis or detachments associated to a macular hole (stages 2c, 3c, 4c) should be immediately treated with combined

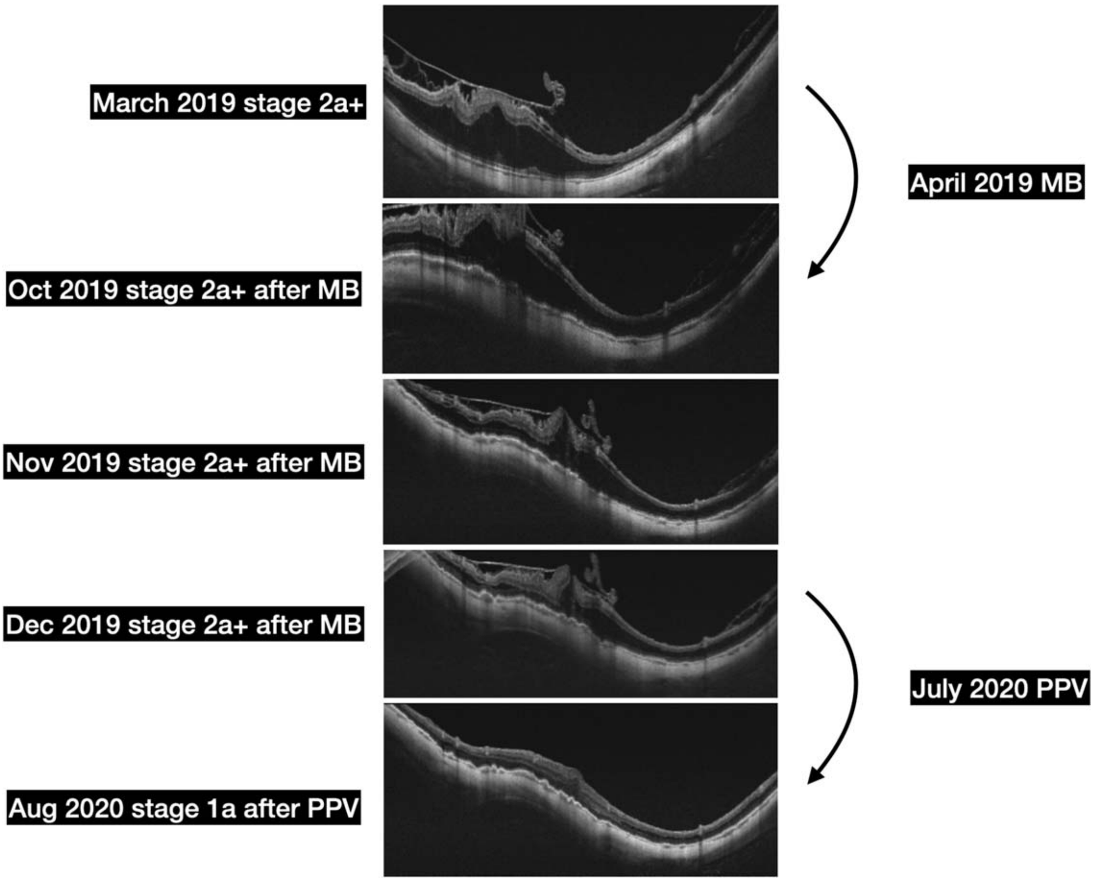


FIGURE 4. Patient with Stage MTM Staging System 2a +. The maculoschisis was treated with MB, obtaining progressive relief in the schisis in more than one year. The persistence of epiretinal proliferation remained significant and the eye was then treated with vitrectomy with improvement in anatomical prophyle and in vision. Best-corrected visual acuity was 0.1 decimal preoperatively, 0.3 decimal after MB and 0.5 after PPV. MB indicates macular buckle; OCT, optical coherence tomography; PPV, pars plana vitrectomy.

MB + PPV to treat simultaneously the retina and the macular hole (Fig. 5). Some cases of MHMD were initially treated successfully only with MB and gas injection, obtaining both the retinal attachment and the complete hole closure. However, years after the first surgery, the authors observed an opening/reopening of FTMH due to the progression of the tangential traction.

In conclusion, the surgical treatment of MTM should be customized surgery per each eye depending on the stage of the disease.

What's the Evidence That This Procedure Improves Vision and Daily Life?

Improvement in vision in operated eyes was demonstrated when the guidelines were followed (data in Press, Macular Surgery Book, Ed Springer). Figure 6 shows the changes in BCVA after each procedure. BCVA improves both using PPV and buckle, but if we follow the proposed guidelines we need a lower number of surgeries per eye to reach the final anatomical and functional result. As an example, if we treat a MD without a hole (stage 3a) only with PPV, we will likely end up with an unresolved MD that will need a buckle to reattach. If we start with a macular buckle, we will reach the final result with 1 surgery instead of 2.

How Macular Atrophy Influences the Choice of Treatment?

Macular atrophy does not influence the choice of surgical strategy (PPV vs MB vs combined). It might influence the choice of treating at all versus not treating. On a personal note, we have noticed that even in presence of atrophy, if we improve the schisis or even more the detachment, the patient function is improved as well. However, this study was not implemented with visual field

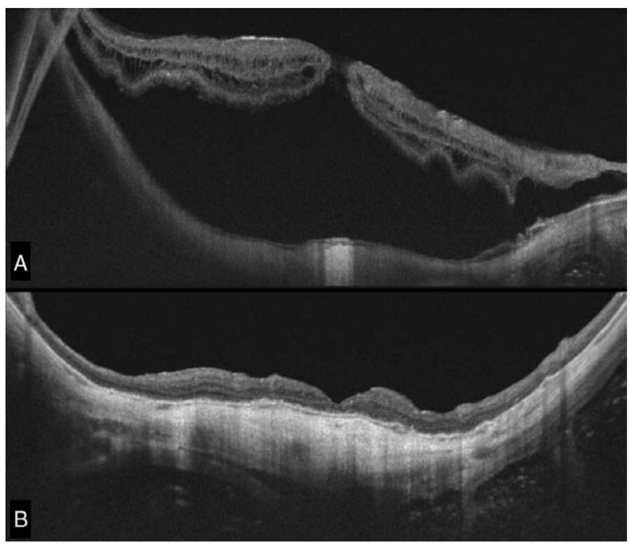


FIGURE 5. A, Macular detachment associated to a macular hole (4C) treated with combined macular buckle (MB) + pars plana vitrectomy (PPV) to treat simultaneously the retina and the macular hole. B, The same eye 3 months after MB + PPV. Best-corrected visual acuity preoperatively was 0.1 decimal and postoperatively was 0.4 decimal.

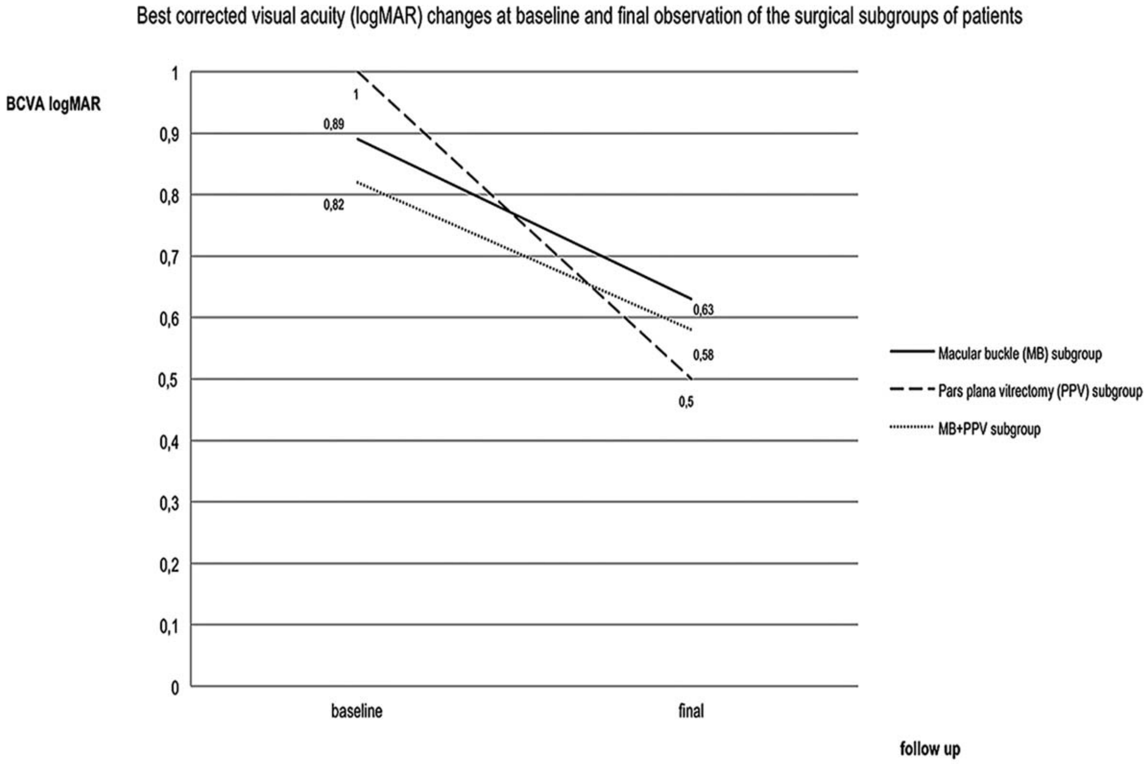


FIGURE 6. Changes in BCVA with different surgical strategies. BCVA indicates best-corrected visual acuity; MB, macular buckle; PPV, pars plana vitrectomy

which would likely support this hypothesis. The atrophy has a grading of severity. We do not have yet the data to know which is the level of atrophy above which it is not useful to offer surgery.

EVOLUTION OF THE SURGICAL TECHNIQUE OF MACULAR BUCKLE

The first technique of macular buckle consisted of suturing a sponge to the sclera behind the macula. This technique was linked to a high rate of complications, mainly the need to detach the muscles to rotate the globe, to suture the buckle behind the macula with difficulty in localizing the fovea and to a high risk of scleral perforation, retinal perforation, and internal bleeding.

Different models have been proposed to overcome this difficulty such as the model of Devin, Ando and Landolfo.[63,64] The idea was to be able to move the sutures anteriorly in a safer and more accessible location. However, even these models did not become widespread.

The first model of MB proposed by Parolini was created by inserting a stainless-steel wire into a silicone sponge, 7-mm wide and 5-mm thick (507 Labtician). The sponge could be bent to an L-shape, with a short side, called head, to buckle the macula, and a long side, called arm, to allow an anterior suture. The MB was inserted by pushing the head behind the macular sclera, through the superotemporal quadrant, leaving the arm parallel to lateral without need of detaching any muscles. The sutures needed to stabilize the arm were placed anteriorly at the level of the insertion of the lateral rectus muscle. The first results were presented at the EVRS meeting in 2009 and at the Heatam meeting in 2009. Later, in 2011, the model was modified by substituting the stainless steel stent with a titanium stent covered by a silicone sleeve (70 Labtician), to avoid the extrusion induced by the sponge. The solid silicone covering the head of the buckle was replaced with a soft sponge, with the aim to avoid atrophy of the RPE induced by acute angles of solid silicone. Moreover, to assess the final position of the MB, the use of a panoramic microscope and 2 optic fibers positioned into the pars plana and into the head of the buckle was adopted. The scleral transillumination helps the surgeon to manage the exact position of the buckle and center it underneath the fovea and in particular underneath the macular hole, if present. The size of the head of the buckle should be 7 mm by 8 to 10 mm to avoid the risk of inducing pain, diplopia, or limitations to eye movement.

The MB is positioned in the superotemporal quadrant with the lateral arm parallel either to the lateral or to the superior rectus muscle. The first option leads to buckle the macula from the temporal side to the nasal side. The second option leads to buckle the macula from 12 o'clock to 6 o'clock and parallel to the optic nerve. This position reduces the risk of optic nerve touch, extrusion, and diplopia.

The final shape of the posterior sclera should be as horizontal as possible, resembling the normal posterior pole. An excessive change in the shape of the macula, with a final convex profile, could induce metamorphopsia, unwanted tangential or excessive refractive modifications. Therefore, the most suitable shape for the head of the buckle. Recently, the intraoperative OCT (iOCT) has been introduced and demonstrated as a useful tool during different kinds of surgery, especially in vitreoretinal surgery.[65] Some authors published regarding the use of iOCT during PPV and ILM manipulation for myopic maculoschisis.[51,66,67]

Parolini et al (data submitted for review) used the iOCT to perform MB without the use of an intravitreal lighting. Thanks to the iOCT, they were able to assess the right position of the buckle, to evaluate the amount of indentation exerted by the buckle and the final shape of the sclera without the positioning of a chandelier light.

How to Select the Amount of Indentation for Each Patient When Implanting a Macular Buckle?

Technically speaking, only with intraoperative OCT we can judge the amount of indentation. However, intraoperative OCT is not widely available. Furthermore, we know that the intraoperative indentation is only an approximation that might change in time due to the intraocular pressure and to the adaptation to the anatomy of the orbit.

Considering these concepts, we decided to standardize the procedure by creating a macular buckle bent with a 90 degree angle between the 2 arms and shaped as an L. Ideally, the final goal is to end with a horizontal shape of the sclera choroidal retina complex and not convex. This goal can be obtain only in certain directions due to the actual shape of the buckle and might be improved in the future.

What Does the Future Hold?

NEW PERSPECTIVES FOR MYOPIC TRACTION MACULOPATHY MANAGEMENT

We foresee for the future the effort to fully understand the treatment of MTM based of the new Staging System. This approach will allow to accurately indicate the best surgical technique and the timing of surgery not for MTM as a whole, but customized on the different stages. With this new perspective we will increase the success rate of surgery and lower the complications of each technique.

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